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MINERALS YEARBOOK



NITROGEN

By Raymond L. Cantrell

1989

U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

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NITROGEN



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October 1990

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COVER PHOTO:
Nitrogen fertilizers
shipped from our
Nation's modern and
efficient production
facilities provide
domestic and
international agriculture
with essential plant
nutrients strategic to
adequate supplies of
global food and fiber.
(Graphic is courtesy of
Agrico Chemical Co., a
unit of Freeport-
McMoRan Resource
Partners.)

NITROGEN MINERALS YEARBOOK—1989

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NITROGEN

By Raymond L. Cantrell

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Planet Earth is surrounded by an atmosphere rich in nitrogen. Nitrogen gas, in fact, accounts for about 78% of the Earth's atmosphere by volume. Nitrogen is an inert gas and reacts chemically only under conditions of high temperature, pressure or through biological processes to produce fixed nitrogen compounds. Ironically, fixed nitrogen (N) compounds are an absolute requirement for life on our planet. A natural phenomenon known as the nitrogen cycle provides a balance between fixed N forms on Earth and atmospheric nitrogen.

Global synthetic ammonia production approached 134 million short tons in 1989 and was valued at about \$15 billion. Fixed nitrogen in the form of synthetic anhydrous ammonia provided the base for the production of food and fiber required to support Earth's estimated 5.2 billion inhabitants. Ammonia also provided for a significant industrial chemicals industry. Synthetic fibers and resins, explosives, and an enormous array of inorganic and organic compounds were dependent upon ammonia feedstock.

U.S. ammonia plants operated at 96% of rated capacity in 1989, in producing 16.8 million product tons. Domestic demand for anhydrous ammonia and downstream nitrogen conversion products was buoyant during the spring of 1989, and producers operated above capacity in meeting demand. Import demand for anhydrous ammonia reached record proportions and the ammonia trade deficit soared to a record 3.4 million tons for the year. An oversupply situation developed in the domestic ammonia market following a disappointing spring fertilizer season, prompting a cutback in production and imports during the second half of 1989.

Ammonia prices fell precipitously during the second quarter and ammo-

nia sold at near producer cash costs f.o.b. plant through the third quarter of the year. Ammonia export and import data were withheld from public disclosure by the U.S. Department of Commerce in 1989, and many industry analysts believed that the loss of strategic trade data required for the monitor of domestic ammonia supply-demand fundamentals served to exacerbate the oversupply situation.

Persian Gulf countries landed 240,000 tons of ammonia in the United States during 1989, representing an increase of 330% above that of the prior year. Kuwait and Bahrain were new entries into the U.S. marketplace and accounted for about 70% of the Persian Gulf total. Saudi Arabia provided the remaining tonnage.

India rejected a Moroccan phosphoric

acid price increase in 1989 and opted to purchase record quantities of U.S. diammonium phosphate (DAP) instead. This unforeseen geopolitical event was fortuitous for both the U.S. nitrogen and phosphate industries and prevented a significant rise in the total U.S. nitrogen trade deficit, while tempering oversupply development in the domestic nitrogen and phosphate markets.

Significant restructuring continued to be experienced in the U.S. ammonia industry during 1989 as evidenced by a flurry of activity in the areas of acquisition and leveraged buyouts that led to further consolidation. Several projects designed to improve energy efficiency and capacity were either completed or in progress.

The U.S. ammonia industry experienced one of its more pronounced

TABLE I
SALIENT AMMONIA STATISTICS¹
(Thousand short tons of contained nitrogen unless otherwise specified)

	1985	1986	1987	1988	1989 ^P
United States:					
Production	14,236	11,909	¹ 13,232	¹ 13,827	13,830
Exports	1,010	531	848	642	381
Imports for consumption	2,306	2,048	2,357	3,032	3,154
Consumption, apparent ²	15,441	13,714	15,193	16,250	16,687
Stocks, Dec. 31: Producers ³	1,795	1,507	1,053	1,020	936
Price per ton, yearend, f.o.b. gulf coast ⁴	\$108	\$75	\$90	¹ \$128	\$87
Net import reliance ⁴ as a percent of apparent consumption	8	13	13	15	17
Natural gas price: Wellhead ⁵	\$2.51	\$1.94	\$1.67	¹ \$1.69	\$1.71
World:					
Production	¹ 100,287	¹ 100,944	103,879	^P 108,448	^P 109,720
Trade ⁶	9,040	7,920	9,080	10,210	^P 10,830

⁴Estimated. ^PPreliminary. ¹Revised.

¹Synthetic anhydrous ammonia, calendar year data; excludes coke oven byproduct.

²Calculated from production, plus imports minus exports, plus or minus industry stock changes.

³Green Markets, Fertilizer Market Intelligence Weekly, McGraw-Hill Inc.

⁴Defined as imports minus exports plus adjustments for industry stock changes.

⁵Monthly Energy Review, U.S. Department of Energy. Average annual cost at wellhead in dollars per thousand cubic feet.

⁶International Fertilizer Industry Association statistics—World Anhydrous Ammonia Trade.

downturns and volatile business cycles during the 1980's. In the early 1980's, domestic commodity businesses were beset by a number of mutual problems, including inordinate energy costs, double digit inflation, global recession, growing international competition, surplus capacity, and rising inventories. The U.S. ammonia industry, in particular, was negatively impacted by prohibitive natural gas feedstock prices, an embargo on U.S.S.R. grain trade, surplus grain inventories, and the emergence of new ammonia capacity in the energy-rich, Government-controlled countries. Obsolete capacity was closed, plants were streamlined, and the industry was restructured. The downcycle ended in 1986, and supply-demand fundamentals gradually improved throughout the remainder of the decade.

DOMESTIC DATA COVERAGE

Domestic production data for anhydrous ammonia were developed by the Bureau of the Census, U.S. Department of Commerce. Preliminary monthly data are published under product code 28731 31 in Current Industrial Reports, Inorganic Fertilizer Materials and Related Products, M28B. Final monthly data are subsequently published in the companion annual report MA28B. The Bureau of the Census surveyed approximately 270 known producers of inorganic fertilizer materials during 1989. Production data are shown in table 1.

LEGISLATION AND GOVERNMENT PROGRAMS

The Natural Gas Wellhead Decontrol Act of 1989, Public Law 101-60, was signed into law on July 26, 1989.¹ This act took the final step in the wellhead decontrol of natural gas by removing those price and nonprice controls that remained in place following the partial wellhead decontrol implemented under the Natural Gas Policy Act of 1978, 15 U.S.C. 3301-3432 (1988). Congress enacted the 1978 legislation in response to severe shortages of gas in the interstate market that occurred in the early to

mid-1970's. The act restructured the regulation of natural gas by merging the interstate and intrastate markets, provided for phased deregulation of most "new" (postenactment) gas, and provided for the continued regulation of "old" (preenactment) gas. The Decontrol Act will serve to repeal the remaining controls by January 1, 1993.

The Environmental Protection Agency (EPA) disclosed the first annual Toxic Release Inventory of chemicals discharged to U.S. air, water, and land required under Title III of the Superfund Amendments and Reauthorization Act (SARA), known as the "Emergency Planning and Community Right-to-Know Act." More than 233 million pounds of ammonia was reportedly emitted into the air by industries in 1987. Ammonia emissions were second only to toluene according to the report. Nitric acid, ammonium nitrate, and ammonium sulfate were also included under title III.

The International Trade Commission rescinded an Antidumping Duty Order imposed against Chilean sodium nitrate in 1983.² The antidumping duties invoked against sodium nitrate landed by Sociedad Química y Minera de Chile, S.A. (SQM) were to be rescinded, retroactive to March 1, 1987.

DOMESTIC PRODUCTION

U.S. ammonia producers operated at 96% of design capacity in 1989. Ammonia production exceeded design dur-

ing the spring because of an expected 6%-10% increase in domestic fertilizer consumption. Production declined markedly in the fall in response to a significant buildup in field inventories. Field inventories were exacerbated by record ammonia imports and marginal growth in fertilizer consumption. Approximately 90% of domestic ammonia production was for fertilizer use. Louisiana, Oklahoma, and Texas provided 60% of U.S. ammonia production; the Southeast and Midwest, 15% each; and the Western States, 10%.

Both ammonium nitrate and ammonium phosphate production was up 6%, in 1989. Urea production declined marginally. Ammonium nitrate demand improved because of its use in the popular urea-ammonium nitrate (UAN) fertilizer solutions and ammonium nitrate fuel oil explosives (ANFO). New production and export records were established for ammonium phosphates in 1989. About 3.5 million tons of ammonia was required to meet the demand for ammonium phosphate production. Acrylonitrile and caprolactam performed well in the industrial sector.

Fertilizer Industries was formed during the year and was reported to have become the largest nitrogen solutions producer in the United States, and second only to Farmland Industries in ammonia production. Between May and November, the conglomerate negotiated the purchase of five nitrogen fertilizer producers in six States. The Arcadian Corporation name was adopted, and headquarters were established in Memphis, TN.

TABLE 2
FIXED NITROGEN PRODUCTION IN THE UNITED STATES

(Thousand short tons of contained nitrogen)

	1985	1986	1987	1988	1989 ^P
Anhydrous ammonia, synthetic: ¹					
Fertilizer	13,024	10,852	¹ 12,019	¹ 12,566	12,503
Nonfertilizer	1,212	1,057	¹ 1,213	¹ 1,261	1,327
Total	14,236	11,909	¹ 13,232	¹ 13,827	13,830
Byproduct ammonia, coke plants: ²					
Ammonium sulfate ^c	50	50	50	60	60
Ammonia liquor ^c	5	4	5	5	6
Total ^c	55	54	55	65	66
Grand total	14,291	11,963	13,287	13,892	13,896

^c Estimated. ^P Preliminary. ¹ Revised.

² Current Industrial Reports, MA28B and M28B, Bureau of the Census.

³ Quarterly Coal Report, U.S. Department of Energy. Production (1985-89) based on reported coke production trend.

TABLE 3

MAJOR DOWNSTREAM NITROGEN COMPOUNDS PRODUCED IN THE UNITED STATES¹

(Thousand short tons)

Compound	1985	1986	1987	1988	1989 ^p
Urea:					
Gross weight	6,975	6,264	7,433	^r 7,914	7,753
Nitrogen content	3,209	2,881	3,419	^r 3,640	3,566
Ammonium nitrate:					
Gross weight	7,149	6,091	6,547	^r 7,504	7,966
Nitrogen content	2,502	2,132	2,291	^r 2,626	2,788
Ammonium phosphates:²					
Gross weight	13,738	11,001	^r 13,352	^r 15,121	16,001
Nitrogen content	2,310	1,861	^r 2,296	^r 2,591	2,721
Ammonium sulfate:³					
Gross weight	2,093	2,080	2,189	^r 2,333	2,354
Nitrogen content	440	437	460	^r 490	494
Nitric acid, direct use:⁴					
Gross weight	2,015	1,939	2,069	^r 2,082	1,743
Nitrogen content	448	431	460	^r 463	387
Acrylonitrile:					
Gross weight	1,174	1,157	1,275	1,288	1,304
Nitrogen content	310	305	337	340	344
Caprolactam:					
Gross weight	545	425	580	631	656
Nitrogen content	68	53	72	78	81
Total:					
Gross weight	33,689	28,957	^r 33,445	^r 36,873	37,777
Nitrogen content	9,287	8,100	^r 9,335	^r 10,228	10,381

^p Preliminary. ^r Revised.¹ Ranked in relative order of importance.² Diammonium phosphate (DAP), monoammonium phosphate (MAP), and other ammonium phosphates.³ Excludes coke plant ammonium sulfate.⁴ Gross nitric acid production adjusted for use in production of ammonium nitrate.

Sources: Bureau of the Census and International Trade Commission.

The firm purchased the plants of Arcadian Corp. at Geismar, LA, and LaPlatte, NE; Columbia Nitrogen Corp. at Augusta and Savannah, GA; Hawkeye Chemical, Clinton, IA; Nitrex at Memphis, TN, and Wilmington, NC; and Olin Corp., Lake Charles, LA. Arcadian's annual production capabilities were reported to be 2.1 million tons of ammonia, 2.9 million tons as nitrogen solution, and 0.8 million tons as urea and ammonium nitrate. The Geismar, LA, facility was also equipped to produce wet-process phosphoric acid and DAP.

Freeport-McMoRan-Agrico announced plans for the sale of its large nitrogen plants at Blytheville, AR, and Verdigris, OK. A new firm, Agricultural Minerals Corp., was organized by Agrico executives to purchase and run the

plants. Big River Inc. was revamping the ammonia plant it had purchased at Helena, AR, and planned to start up late in the year.

El Dorado Chemical Co. purchased American Cyanamid's idle nitric acid plant at Hannibal, MO, and moved the plant and equipment to El Dorado, AR. Ammonium nitrate annual capacity was to increase to 360,000 tons agricultural-grade and 250,000 tons industrial-grade in separate prilling towers. LaRoche Industries Inc. purchased Chevron's idle 550-ton-per-day nitric acid plant at Fort Madison, IA, and moved the unit to its Cherokee, AL facility for nitrogen solutions production. Atlas Powder Co. sold its 230,000-ton-per-year ammonium nitrate plant at Joplin, MO, and associated explosives business to Imperial Chemical Industries

of the United Kingdom. Coastal Chemical Co. expanded ammonia, urea, and ammonium nitrate capacity at Cheyenne, WY. A new 320-ton-per-day nitric acid unit, together with a 400-ton-per-day ammonium nitrate plant, was under construction. Coastal was considering a new nitric acid and ammonium nitrate plant near Elko, NV. Unocal Corp. closed its ammonia plant at Brea, CA, and was constructing new ammonium nitrate capacity at West Sacramento, CA.

The Tennessee Valley Authority (TVA) permanently closed ammonia, urea, and ammonium nitrate plants at Muscle Shoals, AL. TVA reportedly planned to sell the plants.

Cargill Ltd. of the United States and the Province of Saskatchewan announced plans for the construction of a 1,500-metric-ton-per-day ammonia plant and a 2,000-metric-ton-per-day urea plant. The Safarco Products joint-venture plant was to be built in Belle Plaine, Saskatchewan, at an estimated cost of \$400 million. Construction was scheduled to commence during 1990. Government and industry sources from both Canada and the United States debated the potential impact of major new nitrogen fertilizer capacity development in North America.

CONSUMPTION AND USES

Apparent domestic consumption of ammonia in 1989 was 16.7 million tons N. Of this total, 14.2 million tons N, about 85%, could be accounted for in downstream ammonia conversion products and in direct application ammonia fertilizer. Unaccounted disappearance amounted to 2.5 million tons N and was attributable to miscellaneous applications, shifts in field inventories, process losses, and statistical discrepancies.

Approximately 80% of accountable domestic ammonia conversion products was for fertilizer consumption and export. The remaining 20% was consumed in the industrial sector for synthetic fiber and resin manufacture, explosives use, animal feed supplements, and for the production of a wide variety of organic and inorganic compounds.

Urea is the most popular ammonia conversion compound in domestic use because of its versatility and high analysis (46% N). The material is used

extensively as a fertilizer in both solid and liquid form. UAN liquid blends enjoy a commanding share of the nitrogen fertilizer solutions market. In the industrial sector, urea forms the base for urea-formaldehyde resin adhesives and other polymeric materials and finds extensive use as a nonprotein nitrogen source in ruminant animal feeds.

Ammonium nitrate and ammonium phosphates are second to urea in N use. Ammonium nitrate is used predominantly in the fertilizer and explosives sectors. Ammonium phosphates are primary to domestic fertilizer use and export. Nitric acid is used principally for ammonium nitrate production, but about 0.5 million tons, as N, are used for other purposes, including organic chemical synthesis and metal treatment.

Acrylonitrile and caprolactam are used to produce acrylic and nylon fibers, resins, and plastics. Sodium azide (NaN_3) has surfaced as the propellant of choice for air bags, utilized by the U.S. transportation industry for vehicular safety. The material is currently imported, but Virtex Oil & Gas Corp. planned a 2-million-pound-per-year facility at Bristol, VA.

STOCKS

Producer ending inventories did not change between 1988-89 according to available statistics. Field inventories, however, were believed to have increased substantially because of a combination of high domestic capacity utilization, record ammonia imports, and flat domestic fertilizer demand.

TRANSPORTATION

The U.S. Department of Transportation (DOT) reversed an earlier decision to reclassify anhydrous ammonia from a nonflammable gas to a poisonous gas after substantial protest by the public and private sectors. The Research and Special Programs Administration of DOT elected to maintain the current nonflammable classification with the addition of an "INHALATION HAZARD" as a mechanism for hazard communication. DOT, however, extended the response period from October 24,

TABLE 4
DOMESTIC PRODUCERS OF ANHYDROUS AMMONIA IN 1989

(Thousand short tons per year of ammonia)

Company	Location	Capacity ¹
Freeport-McMoRan (Agrico)	Blytheville, AR ²	350
Do.	Donaldsonville, LA	450
Do.	Verdigris, OK ²	950
Air Products and Chemicals Inc.	New Orleans, LA	290
Do.	Pace Junction, FL	100
Allied Chemical Corp.	Hopewell, VA	402
American Cyanamid Co.	Fortier, LA	425
Arcadian Corp. ³	Augusta, GA	545
Do.	Clinton, IA	256
Do.	Geismar, LA	352
Do.	Lake Charles, LA	460
Do.	LaPlatte, NE	190
Do.	Woodstock, TN	340
Big River, Inc. ⁴	Helena, AR ⁵	210
Borden Chemical Co.	Geismar, LA	400
Carbonaire Co. Inc.	Palmerton, PA	35
CF Industries Inc.	Donaldsonville, LA	1,590
Do.	Terre Haute, IN	150
Chevron Chemical Co.	El Segundo, CA	20
Do.	Pascagoula, MS ⁷	—
Do.	St. Helens, OR	80
Do.	Finley, WA	140
Coastal Chemical Co. ⁸	Cheyenne, WY ⁹	200
Cominco American Inc.	Borger, TX ⁵	420
E.I. du Pont de Nemours & Co. Inc.	Beaumont, TX	520
Farmland Industries Inc.	Beatrice, NB	237
Do.	Dodge City, KS	210
Do.	Enid, OK	840
Do.	Fort Dodge, IA	210
Do.	Hastings, NE	140
Do.	Lawrence, KS	400
Do.	Pollock, LA ⁵	420
First Mississippi Corp. (Ampro)	Donaldsonville, LA ⁵	400
Green Valley Chemical Corp.	Creston, IA	35
IMC Fertilizer Group Inc.	Sterlington LA	1,050
Jupiter Chemicals	West Lake, LA	30
LaRoche Industries Inc.	Cherokee, AL	175
Mississippi Chemical Corp.	Yazoo City, MS ⁵	473
Monsanto Co.	Luling, LA ⁵	460
Occidental Chemical Co.	Tacoma, WA	28
Pennwalt Chemical Co.	Portland, OR	8
Phoenix Chemical Co. ¹⁰	East Dubuque, IL	238
PPG Industries Inc.	Natrum, WV	50
J.R. Simplot Co.	Pocatello, ID	108
Sohio Chemical Co.	Lima, OH ⁵	530
Tennessee Valley Authority ¹¹	Muscle Shoals, AL	71
Terra International Inc.	Port Neal, IA	230
Do. (Oklahoma Nitrogen)	Woodward, OK	450
Triad Chemical Co.	Donaldsonville, LA	364

See footnotes at end of table.

TABLE 4—Continued
DOMESTIC PRODUCERS OF ANHYDROUS AMMONIA IN 1989
 (Thousand short tons per year of ammonia)

Company	Location	Capacity ¹
Union Chemical Co. (Unocal)	Kenai, AK	1,200
Do.	Brea, CA ¹¹	280
Wil-Grow Fertilizer Co. ¹⁰	Pryor, OK	94
Total		^r 17,606

¹ Revised.

² Engineering design capacity adjusted for 340 days per year of effective production capability.

³ In late November, Freeport-McMoRan announced plans to sell Blytheville, AR-Verdigris, OK plants.

⁴ Plants purchased late May through early November by Fertilizer Industries, holding company for the Sterling Group and Unicorn Venture Funds.

⁵ Closed March 1989; expected on-stream early 1990 under new ownership.

⁶ Revamp-Retrofit.

⁷ Plant idle.

⁸ Large 530,000 ton per year plant idle for over 2 years; status indefinite.

⁹ Wycon Chemical Co. assumed parent company's name, midyear.

¹⁰ Expansion; 35,000 tons per year.

¹¹ Former N-Ren Corp. plants acquired by Great American Management and Investment, August 1987.

¹² Plant closed midyear.

Source: Economics and Marketing Research Section, Tennessee Valley Authority. World Fertilizer Capacity, Ammonia. Muscle Shoals, AL, Dec. 1989.

1989, to January 30, 1990, following a joint request by the Railway Labor Executives' Association and the Environmental Policy Institute/Friends of the Earth. The status of DOT's plans to formulate a final decision on the issue was indefinite.

Opponents of the original reclassification supplied information that showed anhydrous ammonia retail prices rising by at least \$10 per ton as a result. In addition to a direct price increase at the retail level, the U.S. farmer would have absorbed an added cost in transporting anhydrous ammonia to the farmgate.

Ammonia is transported by rail, truck, refrigerated barge, and pipeline. Koch Industries was operating the Gulf Central Pipeline it purchased in 1988. The 1,900-mile pipeline extends from

TABLE 5
CONSUMPTION TRENDS FOR MAJOR NITROGEN COMPOUNDS PRODUCED IN THE UNITED STATES¹
 (Thousand short tons of contained nitrogen)

	1985	1986	1987	1988	1989 ^p
Fertilizer materials:					
Urea:					
Solid	1,746	1,529	1,904	^r 2,028	1,930
Solution	1,156	1,033	1,137	^r 1,201	1,208
Total	2,902	2,562	3,041	^r 3,229	3,138
Ammonium phosphates ²	2,310	1,861	^r 2,296	^r 2,591	2,721
Ammonium nitrate:					
Solid	850	623	626	^r 776	782
Solution	1,198	963	^r 1,012	^r 1,193	1,265
Other ³	7	43	^r 53	^r 10	104
Total	2,055	1,629	^r 1,691	^r 1,979	2,151
Ammonium sulfate:					
Synthetic and byproduct	440	437	460	^r 490	494
Coke oven byproduct ⁴	52	47	51	59	60
Total	492	484	511	549	554
Total fertilizer	7,759	6,536	^r 7,539	^r 8,348	8,564
Nonfertilizer materials:					
Urea: ²					
Feed	131	107	142	^r 171	98
Industrial	175	212	237	^r 241	331
Total	306	319	379	^r 412	429
Ammonium nitrate ²	447	503	600	^r 647	637
Nitric acid	448	431	460	^r 463	387
Acrylonitrile	310	305	337	340	344
Caprolactam	68	53	72	78	81
Total nonfertilizer	1,579	1,611	1,848	1,940	1,878
Grand total ⁴	9,339	8,147	^r 9,386	^r 10,287	10,441

⁵ Estimated. ^p Preliminary. ^r Revised.

¹ Ranked in relative order of importance.

² Solid and solution.

³ Unaccounted distribution.

⁴ Data may not add to totals shown because of independent rounding.

Source: Current Industrial Reports, MA28B and M28B, Bureau of the Census, and International Trade Commission.

TABLE 6
**U.S. NITROGEN FERTILIZER
CONSUMPTION, BY
PRODUCT TYPE¹**

(Thousand short tons nitrogen)

Fertilizer material ²	1988 ⁷	1989 ^p
Single-nutrient:		
Anhydrous ammonia	3,772	3,800
Aqua ammonia	95	100
Urea	1,529	1,555
Ammonium nitrate	600	649
Ammonium sulfate	158	173
Nitrogen solutions ³	2,167	2,051
Other	34	142
Total	8,355	8,470
Multiple-nutrient: ⁴	2,157	2,163
Grand Total	10,512	10,633

^p Preliminary. ⁷ Revised

¹ Fertilizer years ending June 30.

² Ranked in relative order of importance by product type.

³ Principally urea-ammonium nitrate (UAN) solutions.

⁴ Various combinations of nitrogen (N), phosphate (P), and potassium (K): N-P-K, N-P and N-K.

Source: Economics and Marketing Research Section, Tennessee Valley Authority, Commercial Fertilizers, Dec. 1989.

TABLE 7
**U.S. PRODUCER STOCKS OF
FIXED NITROGEN COMPOUNDS
AT YEAREND¹**

(Thousand short tons nitrogen)

Material ²	1988	1989 ^p
Ammonia	1,020	936
Nitrogen solutions ³	401	442
Urea	170	171
Ammonium phosphates ⁴	124	138
Ammonium nitrate	33	64
Ammonium sulfate	49	53
Total	1,797	1,804

^p Preliminary.

¹ Calendar year ending Dec. 31.

² Ranked in relative order of importance.

³ Urea-ammonium nitrate and ammoniacal solutions.

⁴ Diammonium, monoammonium, and other ammonium phosphates.

Source: Current Industrial Reports, M28B, Bureau of the Census.

the gulf coast into the Midwest, as far north as Iowa. About 3 million tons of ammonia can be transported and stored along its length annually. Mid-America Pipeline Co. (Mapco) was operating a 1,000-mile pipeline that extended from Oklahoma to Minnesota. The Mapco system transports about 1 million tons of ammonia annually.

Seminole Fertilizer Corp. and the Royser Co. operate a joint-venture ammonia pipeline that serves ammonium phosphate producers in Florida. IMC Fertilizer Group Inc. operates a second ammonia pipeline in Florida for the same purpose.

PRICES

Prices for nitrogen products in all forms were firm during the first quarter of 1989. Ammonia prices declined significantly during the second quarter and approached cash costs by mid-May. Urea prices followed a similar trend. Ammonia and urea prices began to improve moderately during the fourth quarter.

Ammonium nitrate was in tight supply for much of the year, and prices were firm through August, after which there was a gradual downturn. DAP prices remained firm through early April, but trended downwards for the remainder of the year.

FOREIGN TRADE

The U.S. Department of Commerce, Bureau of the Census, adopted the new international Harmonized Commodity Description and Coding System (Harmonized System), effective January 1, 1989. The Harmonized System was de-

signed to standardize product codes for items traded in international commerce. Fertilizer and industrial grades of anhydrous ammonia and ammonium nitrate could no longer be distinguished because they were each reported under one code (fertilizer). Several other nitrogen classifications formerly grouped under one code were subdivided.

Total suppression of anhydrous ammonia export and import tonnage data was effected by the Bureau of the Census on January 1, 1989, following the review of a complaint filed by a domestic fertilizer producer. The producer believed that U.S.S.R. ammonia import price information that could be calculated from trade statistics was proprietary and should be withheld from the public domain. Value data by country continued to be reported. The U.S. Fertilizer Institute, the Canadian Fertilizer Institute, industry sources, and the Bureau of Mines worked cooperatively with the Bureau of the Census to develop a base for judging ammonia trade. Tables 9 and 10 were developed as a result of that effort. Late in the year, the Bureau of the Census announced that anhydrous ammonia export and import tonnage data would again be made available to the public in 1990. U.S.S.R. ammonia import tonnage data, however, continued to be suppressed.

The United States experienced a record ammonia trade deficit of 3.4 million tons during 1989. Ammonia

TABLE 8
**PRICE QUOTATIONS FOR MAJOR NITROGEN COMPOUNDS
AT YEAREND**

(Per short ton product)

Compound	1988	1989
Ammonium nitrate: F.o.b. Corn Belt	\$128-\$135	\$105-\$115
Ammonium sulfate: Do.	95- 105	100- 120
Anhydrous ammonia:		
F.o.b. Corn Belt	143- 150	110- 115
F.o.b. gulf coast ¹	126- 129	86- 88
Diammonium phosphate: F.o.b. central Florida	165- 173	125- 126
Urea:		
F.o.b. Corn Belt, prilled	150- 155	110- 120
F.o.b. gulf coast, granular ¹	153- 155	115- 117
F.o.b. gulf coast, prilled ¹	139- 145	98- 105

¹ Barge, New Orleans.

Source: Green Markets, Fertilizer Market Intelligence Weekly, Dec. 26, 1988, and Dec. 25, 1989.

TABLE 9
U.S. EXPORTS OF ANHYDROUS AMMONIA, BY COUNTRY

(Thousand short tons ammonia)¹

Country	1988	1989 ^P
Korea, Republic of	343	171
South Africa, Republic of	101	160
Belgium	94	29
Denmark	—	23
France	—	22
Norway	75	—
Japan	—	23
Morocco	20	—
Tunisia	39	—
Brazil	21	—
Other ²	88	35
Total	781	463

^P Preliminary.

¹ Value data suppressed by Bureau of the Census.

² Twenty-six countries; principally: El Salvador, Venezuela, Costa Rica, Trinidad, Canada, Spain, Taiwan, and Mauritius.

Source: Bureau of the Census (1988); Bureau of the Census and The Fertilizer Institute (1989).

exports declined by 40% and dipped to 0.46 million tons, whereas ammonia imports reached a record 3.84 million tons. A major disruption in world ammonia trade patterns was precipitated in 1989 when India rejected an increase in Moroccan phosphoric acid prices and declined to take the product used to produce domestic supplies of ammonium phosphates. Ammonia shipments from the Persian Gulf that would have normally been landed in India were diverted to the United States and other countries. About 240,000 tons of ammonia was shipped from the Persian Gulf to the United States, a 330% increase over that of 1988. Kuwait and Bahrain, countries that were believed to have never landed ammonia in the United States, accounted for more than 160,000 tons of the total. Ammonia imports from Trinidad also increased substantially. Many industry analysts believed that domestic ammonia oversupply and deteriorating prices were exacerbated by the suppression of U.S. ammonia trade data in 1989.

Overall, the U.S. total nitrogen trade deficit in 1989 was 1.6 million tons N, a moderate 3% improvement over that of 1988. The total nitrogen trade deficit peaked at 2.2 million tons in 1986. Record U.S. export shipments of DAP during 1989 were fortuitous and pre-

vented a significant increase in the total N deficit position. India negotiated record tonnages of U.S. DAP in response to its phosphoric acid price standoff with Morocco. China also imported record tonnages of U.S. DAP.

Urea antidumping actions imposed in 1987 against the German Democratic Republic (GDR), Romania, and the U.S.S.R. protected U.S. producers from unfair trade practices. The GDR was the only country in this group reported to land urea in 1989. According to Bureau of the Census data, the GDR shipped 11,434 tons of urea to the Baltimore, MD, Customs District.

WORLD REVIEW

Global ammonia production exceeded 133 million tons in 1989, establishing a new record. Production facilities in 71 countries provided the vast quantities of ammonia required to supply Earth's 5 billion inhabitants with food and fiber and industrial products. Asia and Eastern Europe commanded 62% of the global ammonia market; North America and Western Europe,

25%; and Latin America and the Middle East, about 10%. Approximately 88% of world ammonia disappearance was for nitrogen fertilizers, and about 12% was for industrial products. About 40% of world ammonia production was converted to urea, and another 10% was traded. International trade of synthetic nitrogen materials in all forms accounted for about 30% of total world ammonia demand.

The ammonia industry operated at 83% of design capacity in 1989, one percentage point below the prior year, and indicative of a relatively soft market. Ammonia production increased 1.5 million tons (1%) between 1988 and 1989, modest in comparison with the 9.1 million ton, 4% average annual growth experienced between 1986 and 1988. Major growth in supply capability has occurred in the centrally planned economies and in other energy-rich, Government-controlled countries during the past decade, whereas negative growth was experienced in the developed economies of North America, Western Europe, and Japan.

Population explosion and feedstock availability have been major factors for capacity development and demand in the developing nations. China and In-

TABLE 10
U.S. IMPORTS OF ANHYDROUS AMMONIA, BY COUNTRY

(Thousand short tons ammonia)¹

Country	1988		1989 ^{c P}	
	Gross weight	Value ² (thousands)	Gross ¹ weight	Value ² (thousands)
Canada	1,571	\$140,131	¹ 1,428	³ \$136,308
Trinidad and Tobago	618	66,599	795-980	92,270
U.S.S.R.	943	91,150	886-898	84,028
Mexico	346	34,512	253-268	22,830
Venezuela	34	3,577	31-57	3,578
Kuwait	—	—	99-133	14,644
Saudi Arabia	56	5,322	61-75	7,166
Bahrain	—	—	32	4,230
Other ⁵	121	13,956	26-69	⁶ 22,498
Total	3,689	355,247	⁷ 3,714- ⁸ 3,837	387,552

^c Estimated. ^P Preliminary.

¹ Tonnage data suppressed by Bureau of Census effective Jan. 1, 1989; alternate sources as described.

² Bureau of Census c.i.f. data, excluding Canadian value for 1989 (see footnote 3). Grand totals as reported by Bureau of Census.

³ Canadian tonnage and value data for 1989 as published by Statistics Canada, courtesy Canadian Fertilizer Institute. Value of Canadian shipments converted to U. S. dollars.

⁴ Canadian ammonia imports in 1989 valued at \$151,706,746 c.i.f., by Bureau of Census.

⁵ Fifteen countries.

⁶ Determined by difference; includes discrepancy between Canadian import value as reported by Bureau of Census (c.i.f.) and Statistics Canada (see footnotes 3 and 4).

⁷ Sum of data reported by The Fertilizer Institute.

⁸ Sum of data reported by Bureau of Mines.

Sources: Bureau of the Census, 1988. Bureau of the Census, The Fertilizer Institute, Bureau of Mines, and Statistics Canada. 1989.

dia compose 40% of world population and are notable examples. Indonesia provided significant quantities of nitrogen fertilizers for domestic use and export. The U.S.S.R. and other Eastern European countries produced ammonia for domestic use and generated strategic supplies of hard currency in the export market.

Significant growth in ammonia supply capability has developed in the Persian Gulf countries where abundant reserves of natural gas feedstock are available. Natural gas was once considered an insignificant byproduct of petroleum production in the Persian Gulf and was commonly flared. Today, natural gas is used to produce value-added ammonia and petrochemical products and liquefied natural gas (LNG) that generate foreign exchange. Iran and Iraq were poised to capture an increasing share of the ammonia market following the signing of a peace accord in 1988.

Ammonia plants in Trinidad and Tobago were strategically positioned to land ammonia in North America and Western Europe. Canada shipped major quantities of ammonia and finished fertilizers to the United States, while Mexico shipped surplus ammonia to the United States.

Capacity

The data in table 12 are rated capacity for ammonia plants as of December 31, 1989. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

World anhydrous ammonia capacity stood at 160 million tons by yearend. Approximately 2 million tons of new capacity came on-stream in 1989, and about 1 million tons of obsolete capacity was permanently closed. Another 5 million tons of ammonia capacity was scheduled to come on-stream during 1990 and 1991. The major feedstock sources for ammonia production were natural gas, naphtha, fuel oil, and re-

TABLE 11
U.S. EXPORTS AND IMPORTS OF MAJOR NITROGEN COMPOUNDS IN 1989

(Thousand short tons)

Compound	Gross weight	Nitrogen content	Value ¹ (thousands)
EXPORTS			
Fertilizer materials:			
Ammonium nitrate ²	145	49	NA
Ammonium sulfate ²	853	179	NA
Anhydrous ammonia	463	381	NA
Diammonium phosphate	9,141	1,645	NA
Monoammonium phosphate	892	98	NA
Nitrogen solutions	283	85	NA
Sodium nitrate	2	(³)	NA
Urea	1,257	578	NA
Mixed chemical fertilizers ⁴	327	51	NA
Other ammonium phosphates ⁵	23	4	NA
Other nitrogenous fertilizers ⁶	183	7	NA
Total	13,569	3,077	NA
Industrial chemicals:			
Ammonia, aqua (ammonia content)	29	24	\$1,827
Ammonium compounds ⁷	2	1	3,628
Ammonium phosphate (ortho)	1	(³)	1,197
Potassium cyanide	2	(³)	2,673
Sodium cyanide	62	18	71,424
Other cyanides and cyanates	1	(³)	3,395
Hydrazine, hydroxylamine, and related inorganic salts	14	7	24,299
Bismuth-silver nitrates	(³)	(³)	8,918
Potassium nitrate	11	2	4,223
Other nitrates	31	6	7,812
Nitric-sulfonitric acids	36	5	19,150
Nitrites	2	(³)	2,266
Total ⁸	192	64	150,813
Grand total ⁸	13,760	3,141	NA
IMPORTS			
Fertilizer materials:			
Ammonium nitrate ²	453	152	\$48,396
Ammonium nitrate-limestone mixtures	12	3	1,155
Ammonium sulfate ²	336	71	27,827
Anhydrous ammonia ⁹	3,837	3,154	387,552
Calcium nitrate	98	15	11,637
Diammonium phosphate	16	3	3,903
Monoammonium phosphate	33	4	10,524
Nitrogen solutions	656	197	60,112
Potassium nitrate	41	5	10,953
Potassium nitrate-sodium nitrate mixtures	44	7	5,453
Sodium nitrate	165	26	20,009
Urea	2,174	1,000	262,407
Mixed chemical fertilizers ⁴	214	26	28,523
Other ammonium phosphates ⁵	57	9	9,529
Other nitrogenous fertilizers ⁶	190	32	32,807
Total ⁸	8,325	4,702	920,785

See footnotes at end of table.

TABLE 11—Continued
U.S. EXPORTS AND IMPORTS OF MAJOR NITROGEN
COMPOUNDS IN 1989

(Thousand short tons)

Compound	Gross weight	Nitrogen content	Value ¹ (thousands)
IMPORTS—Continued			
Industrial chemicals:			
Ammonia, aqua (ammonia content)	62	51	4,939
Ammonium compounds ⁷	14	3	23,800
Calcium cyanamide	1	(³)	431
Potassium cyanide	2	(³)	3,830
Sodium cyanide	29	8	46,736
Other cyanides and cyanates	10	3	11,735
Hydrazine, hydroxylamine, and related salts	4	2	6,221
Bismuth/silver nitrates	(³)	(³)	4,750
Strontium/other nitrates	2	(³)	1,645
Nitric/sulfonitric acids	11	2	2,045
Sodium-other nitrites	4	1	2,259
Total ⁸	138	71	108,392
Grand total ⁸	8,464	4,773	1,029,177

⁶ Estimated. NA Not available

¹ Export values f.o.b.; Import values c.i.f.

² Includes industrial chemical products.

³ Less than 1/2 unit.

⁴ Harmonized codes 3105.10.0000 and 3105.20.0000.

⁵ Codes 3105.51.0000, 3105.59.00 (exports and imports); 3105.40.0050 (imports).

⁶ Codes 3101.00.0000, 3102.29.0000, 3102.60.0000, 3107.90.0000 (exports and imports); 3105.90.0050 (imports).

⁷ Carbonates, chloride, fluorides, and tungstate (exports and imports); bromide, molybdate, orthophosphate, and perchlorate (imports).

⁸ Data may not add to totals shown because of independent rounding.

⁹ Anhydrous ammonia tonnage data as reported by Bureau of Mines; value data, Bureau of Census. Includes industrial ammonia.

Source: Bureau of the Census. Effective Jan. 1, 1989, U.S. exports and imports were reported under the new international Harmonized Commodity Description and Coding System (Harmonized System).

finery off gases and condensates. Other sources included coal gasification, coke oven gases, and electrolysis.

In Canada, ammonia plants totaling 530,000 annual tons were closed by Glacier Ammonia Ltd. at Pincher Creek, Alberta, and by C-I-L Inc. at Courtright, Ontario. Cyanamid Canada Inc. planned to close its 220,000-ton-per-year plant at Welland, Ontario, in 1990. Cargill Limited of the United States and the Province of Saskatchewan let bids for a \$400 million ammonia and urea plant at Belle Plaine, Saskatchewan.

China brought 360,000 annual tons on-stream at Puyang, Hunan, and added 130,000 tons in small plants at various locations. China planned to start up 320,000 tons of small plant capacity in 1990-91 and 360,000 tons at Heijiang, Sichuan, in 1991. In Indonesia, Kaltim started up 360,000 tons at Bontang and PURSI let contracts for 500,000-ton ammonia and 650,000-ton

urea plants at Palembang. In India, Nagarjuna Fert. was to open 330,000 tons at Kakinada in early 1991. In Bangladesh, Jamuna Fert. Co. was to start up 390,000 tons at Jamalpur in late 1991. In the Republic of Korea, Yong Nam closed 120,000 tons at Ulsan in 1989.

Iran was to commence operation of two revamped 360,000-ton-per-year plants at Bandar Khomeini in 1989 and 1990. Iraq was to bring a 360,000-ton plant into operation at Baiji. In Turkey, a 360,000-ton plant was to be brought on-stream by Tugas at Gemlik in late 1990. Libya was to restart its damaged 440,000-ton plant at Marsa-El-Brega in early 1991.

The U.S.S.R. plan to bring 520,000 annual tons on-stream at Rovno, Ukraine, in 1990. Several debottlenecking projects were under way that would result in the addition of another 390,000 tons of capacity during 1991.

In Egypt, SEMADCO was to bring

TABLE 12
WORLD ANHYDROUS AMMONIA
ANNUAL PRODUCTION
CAPACITY, DECEMBER 31, 1989

(Thousand short tons per year of ammonia)

	Rated capacity ¹
North America:	
Canada	4,700
United States	17,606
Total	² 22,310
Latin America:	
Argentina	90
Brazil	1,380
Colombia	170
Cuba	440
Mexico	3,290
Peru	180
Trinidad and Tobago	1,950
Venezuela	900
Total	8,400
Europe, Western:	
Austria	570
Belgium	530
Finland	90
France	2,470
Germany, Federal Republic of	2,880
Greece	470
Iceland	10
Ireland	510
Italy	2,100
Netherlands	4,250
Norway	610
Portugal	450
Spain	960
Switzerland	60
United Kingdom	2,230
Total	18,190
Europe, Eastern:	
Albania	100
Bulgaria	1,830
Czechoslovakia	1,110
German Democratic Republic	2,070
Hungary	1,090
Poland	3,020
Rumania	5,120
U.S.S.R.	33,790
Yugoslavia	1,630
Total	49,760
Africa:	
Algeria	1,130
Egypt	1,150
Libya	380

See footnotes at end of table.

TABLE 12—Continued

WORLD ANHYDROUS AMMONIA ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1989

(Thousand short tons per year of ammonia)

	Rated capacity ¹
Africa—Continued	
Nigeria	380
South Africa, Republic of	830
Zambia	60
Zimbabwe	70
Total	4,000
Asia:	
Afghanistan	80
Bangladesh	1,100
Burma	280
China	25,660
India	11,630
Indonesia	3,840
Japan	2,320
Korea, North	1,200
Korea, Republic of	1,060
Malaysia	380
Pakistan	1,680
Taiwan	340
Vietnam	70
Total	49,640
Middle East:	
Abu Dhabi	380
Bahrain	450
Iran	870
Iraq	810
Israel	90
Kuwait	1,120
Qatar	670
Saudi Arabia	1,170
Syria	380
Turkey	820
Total	6,760
Oceania:	
Australia	730
New Zealand	100
Total	830
Total world	159,890

¹ Includes capacity at operating plants as well as plants on standby basis. Rated capacity based on 340-day-per-year effective operation.

² Data do not add to total shown because of independent rounding.

Sources: Branch of Industrial Minerals, Bureau of Mines, and International Fertilizer Industry Association (IFA).

150,000 tons per year into production at Suez in 1990. A 360,000-ton plant was due on-stream at Abu Qir in early 1991.

Kemira opened a new 280,000-ton-per-year plant at Hull, United Kingdom in mid-1989 and ICI closed 560,000 tons of annual capacity at Billingham and Severnside.

FERTRIN planned to debottleneck its plant at Point Lisas, Trinidad, adding 140,000 tons per year of capacity by 1992. In Chile, a joint-venture project between Kap Resources Ltd. and Atacama Resources Ltd. of Vancouver, Canada, was formed to exploit nitrate deposits in the Atacama Desert. North Lily Mining Co. of San Bruno, CA, was to operate the project. Davy McKee determined that the Yoíanda deposit contained in excess of 20 million tons of "caliche" grading 11.8% sodium nitrate. Additional reserves were expected to be discovered on the property. Sodium nitrate and sodium nitrate-potash chemicals were to be produced.

CURRENT RESEARCH

The M. W. Kellogg Co. of Houston, TX, placed the first large-scale, centrifugal compressor ammonia plant in service in July 1965. The early plants cut ammonia production costs in half and began to replace the smaller and less efficient reciprocal compressor plants. Since that time, the Kellogg large-capacity, single-train ammonia plant design has been used in plants responsible for about one-half of the world's new fertilizer ammonia output.³

Kellogg has recently introduced a new Reduced Energy Ammonia Process that is expected to have a similar revolutionary impact on the nitrogen fertilizer industry worldwide. The total energy requirement is less than 25 million British thermal units (Btu) per ton of ammonia and represents a 25% improvement over feed-plus-fuel values found in conventional plants. Because the feed value is fixed at 18 million Btu per short ton, a 50% savings in the fuel requirement is realized. Kellogg to date has built Reduced Energy Ammonia Process plants in Canada, Belgium, and the Netherlands.

Kinetics Technology International (KTI), Monrovia, CA, has licensed the revolutionary new Leading Concept

Ammonia (LCA) process developed by Imperial Chemical Industries (ICI) of the United Kingdom. The LCA process has been hailed as the most significant breakthrough in small-scale ammonia plant technology in the past quarter century. The total energy requirement for a 500-ton-per-day plant was demonstrated to be 25.2 million Btu per ton. The LCA process separates the ammonia manufacturing operations from the utilities section of the plant, resulting in a low-cost, flexible design.⁴

Deshen International Inc. of Newton, MA, was developing novel technology based on the Birkeland and Eyde electric arc nitrogen fixation process fostered in Norway at the turn of the century. Mr. Mosche Alamaro, Deshen President and Principal Scientist, gave a number of seminars on the subject during 1989. An electric arc in air causes ionization of the nitrogen and oxygen. These charged particles are accelerated by the electric and magnetic fields, resulting in heating of the air. When the temperature of the air rises to 3500 degrees Kelvin, it becomes, according to chemical equilibrium, a mixture including about 5.25% nitric oxide (NO). Rapid cooling results in a solution of nitric acid.

Mr. Alamaro proposed building portable electric arc plants for use in areas where low-cost electricity could be obtained during off peak periods. Deshen reported the potential for the production of nitrogenous fertilizers in several forms using an ammonia-free electric arc process. Mr. Alamaro pointed out that in some respects the process was still in its infancy, allowing for technological breakthroughs in the 1990's that could lead to a competitive advantage for the U.S. industry.⁵

OUTLOOK

World ammonia supplies are expected to be more than adequate to meet global nitrogen demand during the period 1990–95. Ammonia demand in the past has tracked population growth, and this trend is expected to continue. The forecast was developed by taking into account supply and demand projections of the Food and Agriculture Organization of the United Nations (FAO), the International Fer-

TABLE 13
AMMONIA: WORLD PRODUCTION, BY COUNTRY¹

(Thousand short tons of contained nitrogen)

Country	1985	1986	1987	1988 ^p	1989 ^r
Afghanistan ^a	50	44	44	44	44
Albania ^a	88	88	88	88	88
Algeria	^a 165	^a 165	192	217	² 145
Argentina	72	69	79	86	² 82
Australia	446	375	456	425	440
Austria ^a	550	495	495	495	490
Bahrain	121	318	304	340	340
Bangladesh	395	430	480	742	830
Belgium	428	337	296	402	² 320
Brazil	1,042	972	1,049	1,031	² 1,079
Bulgaria	1,254	1,203	1,180	^r 1,160	1,160
Burma	139	147	130	^r 140	130
Canada	3,280	3,208	3,182	3,636	² 3,673
China ^a	16,500	^r 17,100	16,000	^r 17,900	18,700
Colombia	110	103	98	93	² 101
Cuba	180	180	164	149	165
Czechoslovakia	895	838	855	^a 850	848
Egypt	754	789	869	^a 830	830
Finland	72	^r 74	55	47	55
France	2,217	2,229	2,237	^r 2,020	1,630
German Democratic Republic	1,329	1,315	1,296	1,274	1,270
Germany, Federal Republic of	2,103	1,731	2,129	1,929	1,650
Greece	268	266	280	290	250
Hungary	871	840	867	761	830
Iceland	8	9	10	10	9
India ³	4,707	5,438	5,842	^a 6,840	7,400
Indonesia	2,268	2,534	2,606	2,609	² 2,785
Iran	30	73	131	160	² 370
Iraq ^a	66	66	66	345	² 522
Ireland	^r 373	391	440	460	440
Israel	63	63	68	63	66
Italy	^r 1,339	^r 1,712	1,582	1,720	² 1,594
Japan	1,814	1,662	1,715	1,680	1,700
Korea, North ^a	500	500	500	500	500
Korea, Republic of	487	470	523	558	² 529
Kuwait	356	497	637	530	² 733
Libya	453	388	386	^a 300	² 230
Malaysia	59	276	354	331	² 307
Mexico	2,049	1,766	1,922	2,279	2,310
Netherlands	2,773	2,968	3,117	3,258	² 3,308
New Zealand	80	80	^a 80	^a 80	83
Nigeria	—	—	142	342	350
Norway	505	330	383	467	² 421
Pakistan	1,220	^r 1,273	1,300	1,325	1,320
Peru ^a	94	110	88	105	100
Philippines	^a 19	—	—	—	—
Poland	1,997	2,341	2,400	^a 2,425	2,425
Portugal	170	130	171	210	190

See footnotes at end of table.

TABLE 13—Continued
AMMONIA: WORLD PRODUCTION, BY COUNTRY¹
 (Thousand short tons of contained nitrogen)

Country	1985	1986	1987	1988 ²	1989 ³
Qatar	578	600	618	657	660
Romania	3,175	3,352	3,073	⁴ 3,090	2,870
Saudi Arabia	481	514	702	956	965
Somalia ⁵	⁶ 29	⁶ 17	⁶ 8	—	—
South Africa, Republic of ⁶	⁶ 640	⁶ 640	⁶ 600	520	² 502
Spain	664	512	495	525	² 608
Sri Lanka	6	—	—	⁶ —	—
Sweden	20	51	37	—	—
Switzerland ⁶	34	33	43	39	39
Syria	146	151	102	87	² 135
Taiwan	228	292	268	307	225
Tanzania ⁶	(⁴)	(⁴)	(⁴)	(⁴)	—
Trinidad and Tobago	⁶ 1,190	1,258	1,243	1,528	1,700
Turkey	239	219	365	311	330
U.S.S.R.	20,172	21,605	22,050	⁴ 22,160	22,160
United Arab Emirates	311	⁶ 321	333	330	² 357
United Kingdom	1,948	1,530	1,560	1,218	² 1,143
United States ⁵	14,236	11,909	⁶ 13,232	⁶ 13,827	² 13,830
Venezuela ⁶	452	530	⁶ 580	² 481	² 586
Vietnam ⁶	40	40	40	40	40
Yugoslavia	844	897	1,033	946	750
Zambia	19	27	37	18	22
Zimbabwe	76	54	59	71	² 68
Total	⁶ 100,287	⁶ 100,944	103,879	108,448	109,720

⁶ Estimated. ² Preliminary. ³ Revised.

⁴ Table includes data available through May 30, 1990.

⁵ Reported figure.

⁶ Data are for years beginning Apr. 1 of that stated.

⁷ Revised to zero.

⁸ Synthetic anhydrous ammonia; excludes coke oven byproduct ammonia.

tilizer Industry Association Limited (IFA), and Wharton Econometric Forecasting Associates (WEFA). Steady-state conditions were assumed for weather and macroeconomic trends, demographics, and geopolitics.

During the period 1985–90, the growth in demand slightly exceeded the growth in supply capability. Demand averaged 2.1% per year, while supply capability averaged 1.5% per year. Population growth averaged 2.0% per year. The forecast period shows a reversal in the historical trend with growth in supply capability slightly outpacing the anticipated growth in demand. Supply capability is forecast to grow at an average annual rate of 2.5% between 1990–95 and demand at 1.9%. This trend is indicative of a surplus supply situation during the forecast period. Population growth is forecast to average 1.9% per year, in line

with the expected growth in demand.

New ammonia capacity will come on-stream predominately in Asia, Eastern Europe (U.S.S.R.), and the Middle East, in order of importance. The brunt of growth in world demand will be concentrated in Asia and Eastern Europe (U.S.S.R.), followed by selected countries in the Middle East, Africa, and Latin America. Western Europe may experience a moderate decline in demand.

Domestic nitrogen fertilizer consumption in the United States was expected to reach 11.0 million tons N in 1990, a 4% increase. Industry analysts were forecasting 11.2 million tons N consumption for 1991, a 2% increase. The U.S. farm economy has experienced dramatic recovery since 1985. Net cash farm income now stands at about \$55 billion, and there is a good

balance between planted and idled acreage. Planted acreage was expected to approximate 332 million acres in 1990 and 1991, and was projected to range between 330 to 340 million acres in the future. Domestic demand in the industrial sector should continue to grow at an average annual rate of 2%–3% between 1990–95.

A continued resurgence in the U.S. nitrogen sector will be critically dependent upon a number of strategic domestic and international issues and events that unfold during the 1990's. Farm legislation to be enacted in 1990 will establish new domestic agricultural fundamentals for most of the decade. Natural gas deregulation mechanisms will determine the economics and availability of feedstock for domestic ammonia production. Clean air and ground water legislation will influence

TABLE 14
WORLD ANHYDROUS AMMONIA SUPPLY-DEMAND RELATIONSHIPS¹

(Million short tons nitrogen)

	1985	1986	1987	1988	1989 ^a P	1990 ²	1991 ²	1992 ²	1993 ²	1994 ²	1995 ²
Capacity ³	122.9	125.8	126.4	129.9	131.4	132.3	135.0	137.9	141.5	142.6	144.9
Demand: ⁴											
Fertilizer	88.7	89.7	92.4	96.8	98.0	98.9	100.9	102.9	104.8	106.7	108.4
Industrial	11.6	11.2	11.5	11.6	11.7	11.8	11.9	12.1	12.3	12.5	12.6
Total	100.3	100.9	103.9	108.4	109.7	110.7	112.8	115.0	117.1	119.2	121.0
Operating rate ⁵	82%	80%	82%	83%	83%	84%	84%	83%	83%	84%	84%
Consumption:											
Pounds per capita ⁶	41.8	41.2	41.6	42.5	42.2	41.8	41.8	41.8	41.8	41.8	41.7
Population:											
Billion ⁷	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8

^a Estimated. ^P Preliminary.

¹ Calendar years.

² Forecast

³ Design capacity, 340 days-per-year effective operation.

⁴ Ammonia consumed in the production of fertilizer and industrial products, including process losses.

⁵ Total demand as a percentage of design capacity.

⁶ Ammonia demand expressed in pounds per person.

⁷ Statistical Abstract of the United States 1989; Bureau of the Census.

Source: Division of Mineral Commodities, Branch of Industrial Minerals, Bureau of Mines.

domestic production economics and agricultural practices. The impact of consolidation in the European Community in 1992 and the profound restructuring in the Eastern European countries present both problems and opportunities. Capacity development in the energy-rich, Government-controlled sectors will affect supply-demand fundamentals.

BACKGROUND

Nitrogen is mined from the atmosphere through cryogenic air separation and membrane technologies. The global industrial nitrogen gas sector is significant, and in the United States alone, an annual 26-million-ton, \$0.7 billion industry has developed. Industrial nitrogen gas and liquid nitrogen find a variety of uses in the metals, chemicals, electrical, aerospace, food, and cryogenic sectors.

By the early 1900's, global demand for food and fiber had begun to outstrip nature's available supply of fixed nitrogen. World population had doubled in less than a century and approached 2 billion. Fortunately, a major technological breakthrough involving the direct synthesis of ammonia from air and hydrocarbons materialized in Germany.

The Haber-Bosch process revolutionized the concept of synthetic fixed nitrogen manufacture and fostered the technology responsible for today's economic production of ammonia on a large-scale basis.

The basic process for producing ammonia involves the catalytic reaction of a hydrocarbon, usually natural gas, with steam and air to produce hydrogen and nitrogen in the proper ratio to effect ammonia (NH₃) synthesis.

Natural gas is desulfurized and reacted catalytically with steam and then air at about 500 psig to produce raw synthesis gas in a primary and secondary reforming operation. Air is introduced into the secondary reformer in an amount required for ammonia synthesis.

Raw synthesis gas flows to a two-stage carbon monoxide (CO) shift converter for further production of hydrogen. The combined use of high and low temperature shift catalysts permits residual CO to be converted to carbon dioxide (CO₂). The gas is then treated with a regenerative solution for CO₂ removal using physical absorption techniques. Methanation is then effected to convert residual carbon oxides to methane.

Methane is removed, along with argon, from the air in a purge stream from the synthesis loop. Final purification includes the use of molecular sieve drying. The purified synthesis gas is

then compressed and mixed with synthesis loop recycle gas. The combined flow after additional compression is delivered to the synthesis loop where it is converted to ammonia in a horizontal catalytic reactor. Nominal operation pressures are 2000 psig and 3000 psig. Mechanical refrigeration, using ammonia as refrigerant, is used to condense the product ammonia.

Economic Factors

The data of table 15 provide historical trends in ammonia prices f.o.b. plant, natural gas feedstock prices at the well-head, and their mathematical relationship. Ammonia production costs are variably dependent upon natural gas feedstock prices which account for about 70% of the total. Ammonia market prices and indicative profitability are dependent upon natural gas prices, energy efficiency, and market forces.

Ammonia prices experienced a generally upward trend between 1970 and the early-1980's. The cyclical trends in prices are indicative of market conditions and the degree of profitability, and natural gas prices. Ammonia prices and profit margins reached record proportions in 1974-75 when ammonia was in extremely short supply. A firm balance between supply and demand during 1980-81 led to another surge in prices and profitability. Prices trended downwards for

67the remainder of the decade and profit margins were generally weak in spite of declining natural gas prices.

Energy efficiency in the U.S. ammonia industry has been significantly improved during the past 10 years through the closure of obsolete plants and through revamps and retrofits of existing plants. The decline in ammonia-natural gas price ratios between 1970 and the early-1980's demonstrated the sensitivity of ammonia costs to rising natural gas prices. The ratio leveled in 1982 and has been relatively constant since. A return to favorable profit margins in the U.S. ammonia industry will be dependent upon an improvement in world nitrogen supply-demand fundamentals.

¹ Federal Register. Federal Energy Regulatory Commission (Dep. Energy). Order Implementing the Natural Gas Wellhead Decontrol Act of 1989; Final Rule. V. 55, No. 80, Apr. 25, 1990, pp. 17425-17431.

² ———, International Trade Administration/Import Administration (Dep. Commerce). Sodium Nitrate From Chile; Final Results of Changed Circumstances Administrative Review and Revocation of Antidumping Duty Order. V. 54, No. 67, Apr. 10, 1989, p. 14264.

³ The M. W. Kellogg Co. The Reduced Energy Ammonia Process, 1989.

⁴ Kinetics Technology International. Ammonia Technology for the 1990's, 1989.

⁵ Alamaro, M. (Deshen International Inc.). Private Communication, 1989-90; available upon request from Deshen International Inc., Box 128, Newton, MA 02159.

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TABLE 15
TIME-PRICE RELATIONSHIPS FOR U.S. AMMONIA
AND NATURAL GAS

(Dollars per ton and dollars per million Btu)

Year	Ammonia		Natural gas		Ammonia-natural gas ratio	
	Actual value ¹	Constant 1989 dollars	Actual value ²	Constant 1989 dollars	Actual value ³	Constant 1989 dollars
1970	34.00	102.24	0.17	0.51	200	200
1971	34.00	96.72	.18	.51	189	190
1972	35.00	95.06	.19	.52	184	183
1973	43.00	109.72	.22	.56	195	196
1974	93.00	217.52	.30	.70	311	311
1975	148.00	315.22	.44	.94	336	335
1976	107.00	214.17	.58	1.16	184	185
1977	102.00	191.42	.79	1.48	129	129
1978	102.00	178.43	.91	1.59	112	112
1979	107.00	171.94	1.18	1.90	91	90
1980	130.00	191.59	1.59	2.34	82	82
1981	146.00	196.17	1.98	2.66	74	74
1982	141.00	178.08	2.46	3.11	57	57
1983	179.00	168.97	2.59	3.15	54	54
1984	152.00	178.25	2.66	3.12	57	57
1985	140.00	159.44	2.51	2.86	56	56
1986	102.00	113.20	1.94	2.15	53	53
1987	98.00	105.43	1.67	1.80	59	59
1988	105.00	109.33	1.69	1.76	62	62
1989 ^P	100.00	100.00	1.71	1.71	58	58

^P Preliminary

¹ Value of shipments, f.o.b. plant, in dollars per ton.

² Value at wellhead, in dollars per million Btu.

³ Ratio of ammonia value to natural gas value.

Sources: Bureau of the Census (ammonia prices); Department of Energy (natural gas prices); Council of Economic Advisors (1989 implicit price deflators for gross national product).